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ORIGINAL ARTICLE

Factors influencing silvicultural value of cultures of silver fir *Abies alba* Mill. at higher altitudes in the Beskid Śląski and Beskid Żywiecki Mountains

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Abstract

This paper provides results of an assessment on the survival rate, quality and vitality of seedlings of European silver fir *Abies alba* Mill. in forest cultures five years after plantation. The assessment took place in autumn 2006. Measurements and scorings were made in the cultures (plots), and tree groups within them. Similarities and differences were analyzed at plots located in different forest regions and forest districts, with regard to the extent of canopy disintegration, and the presence or absence of protection against game.

The results indicate poor condition throughout many parts of the European silver fir cultures. Generally, the quality and vitality of the seedlings was assessed to be average, with a smaller or larger tendency towards further deterioration. This points to difficulties in performing stand regeneration and in diversifying tree species composition in the higher locations of the Beskid Śląski and Beskid Żywiecki Mts, which experience extreme climatic conditions. This was particularly noticeable with respect to tree height and quality parameters, which were worsening along with an increase in the degree of canopy stand disintegration.

Many European silver fir seedlings grew better on the fenced plots than on the unfenced, which indicates the need for protection of cultures against game and justifies the use of fencing.

Key words

survival, quality, vitality, game damage, final silviculture assessment, *Abies alba*

Introduction

Since the 17th century, the forest stands of the Beskid Śląski and Żywiecki Mts have been undergoing unfavourable changes impairing their environmental stability. In the past, the proportion of spruce was increased at the expense of deciduous species and fir in this part of the Carpathians, and monocultures composed only of spruce, often of foreign origin, were introduced in place of former beech-fir stands. Forest management did not take site conditions into account and pursued only economic goals: focusing on providing large amounts of timber and providing an income for forest owners (Kawecki 1939; Broda 1965). This reduced resistance to the threats caused by natural factors – biotic and abiotic. The rapid growth of industrial pollution has

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led to damage of trees and habitat (a reduction in air and soil quality, and contamination with heavy metals), as well as to the depletion of forest biocoenosis, which has reduced the resilience of these forests (Małek 2010). However it is the many years of promoting spruce monocultures, lasting until the turn of the twentieth and twenty-first century, the slow and negligent reconstruction of stands, as well an increase in the rotation of planted spruce stands to periods as long as 120 years, that are the factors most frequently advocated as having contributed to the current unfavorable condition of spruce stands in the Beskidy Mts. These factors, in combination with those previously mentioned, have led to the deaths of individual trees, followed by the decline of tree groups, stand sections and, in recent years, the dieback of whole stretches of forest. This is particularly evident at high altitudes (Capecki 1994; Troll 1995; Barszcz and Małek 2006), where it is considered a result of a multi-factor forest disease (Sierota 1995). In addition, there are problems with artificial regeneration of those species (beech, fir, and sycamore), which are in the future intended to diversify the species composition of stands in this region. The current situation of forests in the Beskid Śląski and Żywiecki Mts requires responsible and thoughtful forest management, restoring the permanence and balance of the forest ecosystem. The objective of a carefully planned reconstruction of monoculture spruce stands in this region should be one of multi-species stands, with a multi-storey structure, composed of several generations of trees growing in groups or clumps (Jaworski 2000). The fast pace of degradation of the existing stands, unfavourable climate and soil, damage caused by deer and an insufficient seed base adapted to local environmental conditions, are the main elements hindering the process of reconstruction and regeneration of forest stands in the Beskid Śląski and Żywiecki Mts (Barszcz and Małek 2006). The advancing process of environmental degradation, resulting in a decrease in forest health is a challenge that must be met by intensive methods of forest management, including forest regeneration and forest culture protection which need to be employed for the restoration of forest in these areas.

Red deer *Cervus elaphus* L. are frequently cited as a factor inhibiting and limiting forest reconstruction and regeneration in the area analysed (Capecki 1986, 1994; Barszcz and Małek 2003). The protection of forest against deer includes both the basic (technical), and the subsidiary (ecological) methods (Instrukcja Ochrony Lasu 2004). The former include the protection of individual trees or tree groups by using repellents, screens or fences; the latter include measures used to maintain the population of deer at a level that ensures optimum effectiveness of the basic methods, as well as those used to enrich or adapt the environment to the needs of the deer. In practice, technical methods are the most frequently used i.e. the mechanical protection of regenerated areas or individual trees exposed to damage. According to Szukiel (2002) and Kubacki (2008), the most effective method among the mechanical is suitable fencing of areas, which keeps deer away from cultures, young stands, and individual trees. In the literature this thesis remains to be statistically confirmed, which would help to clearly assert the positive impact of fencing. In our study area, fencing was performed in order to protect sections of cultures containing fir.

The main objective of this study was to provide a final assessment of the reforestation success of cultures with fir located at the altitudes between 900 and 1200 m above sea level in the Beskid Śląski and Żywiecki Mts, combined with a detailed analysis of the vitality and quality of seedlings of this species, which was, historically along with spruce and beech, the main component of forests in this region.

Methods

The study was conducted at nine research plots of the Department of Forest Ecology at the University of Agriculture in Krakow (no: I, III, IV, V, VI, VIII, IX, X, XX), situated in the Beskid Śląski and Żywiecki Mts (Tab. 1). The cultures in the present study are located in areas of and around mountain ridges, at altitudes of 900 to 1200 m above sea level. The plots were set up in the spring of 2002 by forest service contractors, which were supervised by the employees of local forest districts.

The research plots are located in four forest districts of the Regional Directorate of the State Forests in Katowice: Ustroń (I, III, IV), Wisła (V, VI, VIII), Bielsko (IX, X) and Jeleśnia (XX) on the same soil type (dystric cambisols), and the same site type, being of mountain

mixed coniferous forest. Annual average temperature and precipitation between 2002–2007 are presented in Tab. 1 according to Feliksik and Durło (2004), and Durło (2007, 2010, 2011, 2012).

The research plots were rectangular and their boundaries were marked by wooden poles in their corners. In order to assess the impact of fencing, nine of the plots (I, III, IV, V, VI, VIII, IX, X, XX), were subdivided into two parts: a fenced /G/, and an unfenced / NG/, each 100 m^2 with three replications. The cultures were distributed unevenly, i.e. set up in different areas and stands, to prevent a concentration of deer damage from occurring to the unfenced stands by deer inhabiting nearby areas.

Seedlings for the experiments were provided by each forest district. However, it was impossible to obtain reliable information on their origin (location and elevation) and exact age. It must be assumed that indigenous seedlings from local nurseries were planted. Their age was estimated in 2006 as ranging from six to nine years.

Research plots were established in stands at varying degrees of disintegration, as well as on open surfaces, thus providing different degrees of culture protection. This was intended to permit an examination of the impact of the canopy, or lack thereof, on the quality and vitality of silver fir seedlings.

Classification of the stands to the degrees of disintegration followed Barszcz et al. (2009):

– SZ – very urgent reconstruction required within a very short period (up to a few years), which should include the following stands: the dying, where the harvesting of sanitary deadwood (NPS) is above 50 m^3/ha a year, which corresponding to an active deadwood increase index (NPC) of over 16, tree coverage in the stand canopy of 0.1–0.3, and a degree of coverage with a young generation of 0.1–0.3;
– ŚRZ– urgent reconstruction required within a relatively short period (up to several years), which should include the following stands: the weakened, where the harvesting of sanitary deadwood (NPS) is 30–50 m^3/ha a year, corresponding to an active deadwood increase index (NPC) of 10–16, stand tree coverage canopy of 0.4–0.5, and a degree of coverage with a young generation of 0.4–0.5;
– ST (2) – relatively urgent reconstruction required within a longer period (within 20–30 years), which should include the following stands: the weakened, where the harvesting of sanitary deadwood (NPS) is below 30 m^3/ha a year, corresponding to an active deadwood increase index (NPC) of below 10, stand tree coverage canopy of 0.5–0.7, and a degree of coverage with a young generation above 0.5.

The involvement of individual forest districts was also assumed to be important. This includes, among other factors, the quality of afforestation by contractors and the standard of the chosen and consistently implemented method of protection against deer (proper maintenance of fences and periodical checking of their condition). These activities, or lack of them, had a direct effect on the current state of the cultures assessed.

In the autumn of 2006, when the growth of seedlings had ceased, i.e. after the fifth growing season from plantation, measurements and evaluation were performed using the same methodology as was used in the initial assessment of the cultures. The field work included:

– Scoring the quality of seedlings on the scale: 1 – good: when the stem is straight, the tree branches evenly, without defects and damage; 2 – medium: when the stem is slightly bent, the crown is slightly less developed, with minor damage to the lateral shoots; 3 – bad: when the stem is largely bent, the crown is short and unevenly developed, the seedling has large damage and numerous defects (such as multiple tops, doubles, regeneration after injury, etc.)
– Scoring vitality on the scale: 1 – viable: when the leaves are large, dense and dark green, and there are large top buds; 2 – medium viable: when the leaves are more delicate and medium-sized, buds and increments are slightly smaller; 3 – weakened: when the leaves are scarce, small and pale, increments are small and buds are poorly developed. The numbers of dead seedlings were also determined, and the presence of injuries and defects were identified in young trees.

For all types of tree features, basic statistical characteristics were calculated and the strength of correlations between them was estimated. A comparison of the average values of the selected features between the fenced and the unfenced plots was made using multidivision tables (Łomnicki 2005; Rutkowska and Socha 2006).

Apart from measures which differentiated the variants of cultures containing the examined species, the statistical analysis included:

– location of these cultures in different forest districts
– the impact of the canopy on stands at varying degrees of decline, or the absence of any canopy (open space research plots).

The final silvicultural assessment (numerical) was performed in accordance with the recommendations of the Forest Management Rules (Zasady Hodowli Lasu 2003). It was based mainly on the degree of survival, vitality, quality, and the proportion of trees with defects. The descriptive assessment was made in accordance with the Forest Management Rules modified by Barszcz and Małek (2010).

Results and discussion

Silver fir seedling survival in the five-year cultures ranged from 17.5% (IXB/G-fenced/) to 87.0% (IIIA/G/) (Tab. 1). The positive impact of fencing in this regard

Tab. 1. Percentage of survival, tree coverage, silvicultural value, and reforestation success in 5-year-old silver fir cultures on research plots in 2006. Scoring followed the Forest Management Rules (2003), as modified (**) by Małek et al. (2010) regarding the success of reforestation

Code	Degree of disintegration of canopy stand	Fencing (G – fenced, NG – fenceless)	Survival rate (%)	Tree cover degree (score)	Silvicultural value (score)	Reforestation success** (score)	Overall evaluation
I	ŚRZ	G	73.5	2	1	2b	Good cultures
I	ŚRZ	NG	86.8	2	2	2c	Good cultures
III	ŚRZ	G	87.0	2	3	3a	Satisfactory
III	ŚRZ	NG	59.5	3	4	3g	Not very satisfactory**
IV	ŚRZ	G	60.0	3	4	3g	Not very satisfactory**
IV	ŚRZ	NG	69.0	3	3	3d	Medium satisfactory**
V	U	G	70.0	3	4	3g	Not very satisfactory**
V	U	NG	57.8	3	4	3g	Not very satisfactory**
VI	ST(2)	G	57.8	3	3	3d	Medium satisfactory**
VI	ST(2)	NG	47.5	4	4	4d	Lost
VIII	SZ	G	43.3	4	4	4d	Lost
VIII	SZ	NG	33.0	4	3	4c	Lost
IX	SZ	G	17.5	4	4	4d	Lost
IX	SZ	NG	46.0	4	4	4d	Lost
X	U	G	65.2	3	4	3g	Not very satisfactory**
X	U	NG	76.9	2	3	3a	Satisfactory
XX	ŚRZ	G	80.0	2	4	3f	Not very satisfactory**
XX	ŚRZ	NG	30.2	4	3	4c	Lost

Degree of disintegration of a canopy stand: ST-2 – stable stand; ŚRZ – under medium threat, SZ – under serious threat, U – cultures in open areas after stand disintegration

was observed on most research plots (III, V, VI, VIII, XX). Statistical analysis confirmed the significance of differences in favour of fencing in two cases (III, XX) (Tab. 2).

The initial comparison of plots established under the canopy of stands at different stages of disintegration, and including the open areas, revealed the that lowest survival rates were in the cultures located in spruce stands under serious threat of disintegration – SZ (G: 30.4%, NG: 39.5% – an average of 35.0%); successively higher values in stable stands – ST (2) (G: 57.8%, NG: 47.5% – an average of 52.7%), higher again in stands under medium threat of disintegration – SRZ (G: 75.1%; NG: 58.8% – an average of 66.1%), and highest in the cultures in open areas – U (G: 67.6%, NG: 65.5% – 66.3% on average). Having said that, during the final assessment the poorest survival rates were found to be for fir trees in cultures after the complete disintegration of the stand – U (G: 45.1%, NG: 49.1% – an average of 47.4%); the survival rate was the highest in cultures growing in spruce stands under the medium threat of disintegration – SRZ (G: 75.1%, NG: 58.8% – an average of 66.1%) (Tab. 2).

The mean survival of fir seedlings across all plots was significantly lower five years after planting (58.6%), than 2 years after planting (71.7%). Although significantly smaller numbers of seedlings survived on all plots, higher survival rates were observed on the fenced plots (G: 61.6%, NG: 56.1%). Additionally, survival rates fell down to quite low levels in the group of fenced plots, wherever the damaged fences were not repaired.

The average quality of the trees after the fifth year of growth in cultures ranged from 1.4 (IA/G/) to 2.9 (VIB/NG/), and in general it may be regarded as "mean". The same grade was observed during the previous assessment. The positive impact of fencing on quality was noted on most plots (I, III, VI, VIII, XX), and was confirmed statistically for three of them (I, III, VI) (Tab. 2).

In 2003, the quality of seedlings in the fenced sections was better in comparison with those in the unfenced on six plots (I, III, V, VI, X, XX), and the difference was statistically significant in all cases.

The average value of the seedling vitality ranged from 1.7 (IA/G/) to 3.0 (VIB/NG/); and it may be regarded as a "mean" vitality. Five years after planting, the positive response of vitality to fencing was noted on most research plots (I, III, V, VI, IX, X, XX), and the difference was statistically significant on three of them (III, VI, IX) (Tab. 1).

The assessment performed in 2006, showed a slight improvement in both quality and vitality. This was more visible on the fenced plots than on the unfenced.

Tab. 2. The response of the assessed features of silver fir to fencing on the research plots in 5-year-old production cultures in the Beskid Śląski and Żywiecki Mts with their location

Code	Forest District	Geographical possition of studied cultures		Anual average temperature within 2002–2007 (°C)	Anual average precipitation within 2002–2007 (mm)	Assessed features and scoring		
		N	E			Survival	Quality	Vitality
I	Ustroń	49° 40' 8.23''	18° 57' 31.77''	5.5	1340	–	+	+
III	Ustroń	49° 40' 7.88''	18° 57' 31.73''	5.5	1340	+	+	+
IV	Ustroń	49° 40' 6.38''	18° 57' 31.66''	5.5	1340	(–)	–	–
V	Wisła	49° 39' 32.55''	18° 58' 45.94''	4.6	1405	(+)	(–)	(–)
VI	Wisła	49° 39' 31.85''	18° 58' 47.56''	4.6	1405	(+)	+	+
VIII	Wisła	49° 39' 30.62''	18° 58' 48.67''	4.6	1405	(+)	(+)	(+)
IX	Bielsko	49° 40' 51.97''	19° 1' 16.97''	4.4	1425	(–)	(–)	+
X	Bielsko	49° 40' 50.55''	19° 1' 17.83''	4.4	1425	(–)	(–)	(–)
XX	Jeleśnia	49° 32' 16.12''	19° 14' 24.85''	4.2	1430	+	(+)	(+)

Explanations: Statistically significant response of an analysed feature of seedlings to fencing on the level of significance $\alpha = 0.05$: "+" – positive and statistically significant response; "–" – negative and statistically significant response. In paranthiesies signifies the remaining responses statistically not significant but with a positive "(+)" or a negative tendency "(–)".

The differences were statistically significant in those forest districts in which the fencing of plantations was properly maintained (Ustroń and Wisła).

With regard to the quality of trees, substantial differentiation was observed between the groups of cultures set up under the canopy stands at different degrees of disintegration and in open areas. The poorest were fir trees planted under the canopies of fairly stable stands – ST (2) (G: 2.3; NG: 2.9). The best in this respect were trees on fenced plots, under the canopy of spruce stands at medium risk of disintegration – ŚRZ (G: 1.7; NG: 2.1). Fencing was confirmed to have a positive impact statistically in the group of plots established in stable stands, and in stands under medium threat of disintegration – ST (2) (G: 2.3, NG: 2.9); – ŚRZ (G: 1.7, NG: 2.1) (Fig.1).

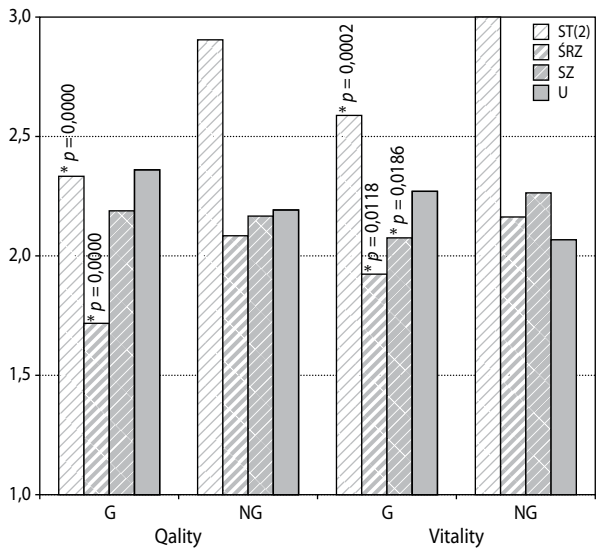

Fig. 1. The average quality and vitality in 5-year-old production cultures with silver fir in groups of research plots set up under the stands with different degrees of disintegration and on an open plot in the Beskid Śląski and Żywiecki Mts

Explanations: ST-2 – stable multi-species stands; ŚRZ – stand under average threat of disintegration; SZ – stand under high threat of disintegration; U – new cultures established after forest dieback; G – fenced plots; NG – unfenced plots; * – statistically significant positive response of the analysed seedling score to fencing at the level of significance $\alpha = 0,05$; p – level of probability.

The vitality of seedlings from the five research cultures followed a similar pattern as the quality. The poorest vitality was recorded for fir trees on the fenced and unfenced plots set up in stable spruce stands (G: 2.6; NG: 3.0). Trees in stands under medium threat of disintegration, growing on both plot variants, scored highest for vitality (G: 1.9; NG: 2.2). The positive response of fencing on vitality was confirmed statistically in most of the analysed groups of plots – ST (2) (G: 2.6, NG: 3.0); – ŚRZ (G: 1.9, NG: 2.2); – SZ (G: 2.1, NG: 2.3) (Fig.1).

The overall assessment of the silvicultural value of five-year-old cultures with silver fir, located at higher altitudes of the Beskid Śląski and Żywiecki Mts, is presented in Tab. 2. The assessment followed the Forest Management Rules (Zasady Hodowli Lasu 2003), and consisted of the coverage of the plot by young trees (corresponding with their survival rate), and of the production value which includes the species composition, health, defects, and culture's ability to adapt to the site. Due to the lack of data about the origin of the seedlings with regard to the location and elevation of their source population, their adaptation to the site was not assessed.

Out of the eighteen cases of cultures included in the present research, six cultures were classified as lost (VIB /NG/ VIIIA /G/, VIIIB /NG/, IXB /G/, IXA /NG/, XX /NG/). Another X were assessed as low and medium satisfactory, two were good (Ustroń Forest District IA /G/ and IB /NG/), and two plots (Ustroń III A /G/ and Bielsko XB /NG/) were assessed as satisfactory cultures (Tab. 2).

Summary and conclusions

- Difficult site conditions in the higher altitudes of the Beskid Ślaski and Żywiecki Mts, intensified by the negative impact of anthropogenic factors, affect to a very large extent the older stands but also young trees and threatened the existence of forest cultures.
- Fencing of cultures had a positive effect on the survival, quality and vitality of silver fir seedlings. This illustrates the advantages of fencing these valuable species in forest cultures in order to obtain better results from reconstruction of the disintegrating stands. The positive impact of fencing in this case is clear and often statistically significant. This method of protection must be maintained consistently, however. Fences need to be checked periodically and also after each windstorm and heavy snowfall, and damage needs to be repaired as soon as possible.

- Overall quality and vitality of fir trees in the cultures studied was assessed as "average", with a greater or lesser tendency to deterioration in the future. This shows, *inter alia*, the difficulties in carrying out stand restoration and in enriching the stand composition with this species at higher altitudes. This also makes it necessary to consider any additional factors that could be eliminated from the practice in order to increase the proportion of this valuable species in the higher altitude locations.
- The reforestation success of fir cultures, was assessed as "moderately satisfactory" on average. This is mainly the result of the increased mortality of young trees within five years of planting. Although it turned out to be impossible to determine the origin of planted seedlings, the low final survival rate in the cultures examined may have also been influenced by the location of their source seed stands at different elevations and site conditions.
- The present findings should enforce greater care in setting up forest cultures, their management and planned activities related to the reconstruction of stands in the Beskid Śląski and Żywiecki Mts. Satisfactory performance in the reconstruction of spruce stands in this region requires high quality planting material compliant with binding regulations in this matter, measures taken to diversify the tree species composition by including species such as fir, beech, and sycamore, and the protection of these cultures against damage from deer.

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